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COAXIAL CABLE WITH CONFOCAL CROSS SECTIONS OF THE CYLINDERS

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The theory of the propagation of electromagnetic waves along a coaxial cable with ideally constructed conductors is well known. However, this case is not encountered in practice since, as a result of technological difficulties, the coaxial cables produced have a number of structural nonhomogeneities: the cable cylinders are often deformed and are not perfectly round; the diameters of the cylinders are not the same along the entire cable length and strict concentricity is not maintained; the dielectric constant of the insulation supporting the inner conductor may vary within certain limits, etc. These irregularities create ideal conditions for multifold reflections of the electromagnetic waves, which cause distortion of the signals being transmitted -- a condition which is particularly undesirable in the case of television transmission.

Determination of the permissible magnitudes of nonhomogeneities is a most important engineering problem. Its solution will permit tolerance norms to be established for the production of coaxial cable which as yet have not been agreed on by the International Consultation Committee. The approach to this problem has been simplified by previous work which makes it possible to consider that the inner and outer metallic conductors have finite, rather than infinite, conductivity. For the case of finite conductivity, the slight axial component of the electric field intensity wave must be taken into consideration.

In calculating the effects of deformation of the conductors of a coaxial cable upon its parameters, it was assumed that the dielectric is homogeneous and that the irregularity is uniform along the entire cable length. The problem was solved by the method of conformal representations assuming both metallic conductors to be ideal so that the axial component of the electric field intensity vector disappears. A shortcoming of this method is the absence of

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the coefficient of absorption in the final formulas. At high frequencies, however, the longitudinal absorption may easily be calculated. In this case, the tangential component is considered to be approximately the same both for ideal conductors and for conductors with finite, but high, conductivity. To make this assumption, however, the maximum absorption must not reach values for which it would influence the field structure in the separate transverse cross sections. This condition would only appear at frequencies of 10^{11}-10^{12} cycles per second, and thus both conductors may, at first, be considered to have infinitely great conductivity. After having calculated the intensities of the electric and magnetic fields, it is then possible to calculate the losses due to the finite conductivity of the metal, bearing in mind the shallow penetration of the field into the metal at high frequencies. Ya. N. Fel'd and L. A. Zhekulin assumed such conditions to solve a number of engineering problems. These same assumptions are widely used in calculating losses and the coefficient of energy absorption in wave guides.

Formulas obtained by L. A. Zhekulin (Izvestiya Akedemii Nauk, Otdeleniye Tekhnicheskikh Nauk, No 9, 1947) for the characteristic impedance, density distribution of surface currents, coefficient of absorption, and effective resistance for ideal conductors are used as the groundwork for solving the case of a cable whose conductors have a confocal cross section.

To find the characteristic impedance for the latter cable, the author first derives a power-series expansion of the logarithm of the ratio of outer radius to inner radius in powers of the ratio of the major semiaxis of the confocal cable and of the eccentricity. This expansion is substituted for the logarithm in Zhekulin's formula. Similar substitutions of the geometric parameters of the confocal cable are made in Zhekulin's formulas for the density distribution of surface currents, coefficient of absorption, and effective resistance of ideal conductors.

Formulas were derived for these quantities as functions of the geometric parameters for conductors having elliptical cross sections, and a number of graphs was constructed. The curve showing the relationship between the characteristic impedance of a confocal cable (in percent of the characteristic impedance of a perfectly circular cable) and the relative eccentricity (absolute eccentricity divided by major semiaxis) of the outer conductor was parabolic (concave upward, starting from the origin). Other curves showed that the proximity effect is more marked for the inner conductor than for the outer conductor with an increasing relative eccentricity. Curves were also plotted showing the relationship between the coefficient of absorption of a confocal cable, expressed in percent of the coefficient of absorption of an ideally constructed cable, and increasing relative eccentricities (from 0 to 0.20) of the outer conductor, and the dependence of the ratios of the resistances of elliptical (inner and outer) conductors to the resistance of ideally constructed (inner and outer) conductors upon the relative eccentricity of the outer conductor.

Inasmuch as the tolerance norms for the production of coaxial cable have not been definitely established as yet, the results obtained yield additional information for clarifying the problem of the effect of irregularities upon the characteristic impedance, attenuation constant, and effective resistance. The permissible deformation of the cable for maintaining the characteristic impedance within assigned limits may be determined from the graph.

In conclusion, curves showing the characteristic impedance and attenuation constant for three different types of cables are introduced for comparison. The three are: a cable with confocal cross sections of the cylinders; a cable with cylinders whose axes are not coaxial; and a cable with deformed cylinders (cross sections bounded by cardiod curves).

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It was found that the characteristic impedance curve for the confocal cable took an intermediate position between the other two curves, and that the absorption for this cable was less than that of the other two cables for the same relative distortions.

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